2.2 Watershed Imperviousness Determination

Another parameter that is required to develop estimates of average annual runoff volume, TP and TSS loadings is imperviousness. Imperviousness was estimated using satellite-derived (LandSat) data developed by the University of Minnesota for the MPCA. These data are available for the entire Twin Cities Metropolitan areas for the years 1986, 1991, 1998, 2000, and 2002.

Once the Bloomington land use for 1989 and 2007 was reclassified with a consistent land use system, the percent imperviousness by land use was determined by overlaying the Bloomington 1989 land use with the 1991 LandSat-derived estimates of imperviousness for the Twin Cities metro area as well as a comparison of the 2007 land use data with the 2002 LandSat derived estimates of imperviousness.

With the exception of a few small areas, much of the city of Bloomington was completely developed by 1989, and it was assumed that the average percent impervious by land use for 1989 and 2007 would be applicable for the load calculations for all years of analysis. Additionally, a comparison of the 2000 impervious percentage coverage for Bloomington with the 2000 Met Council Land Use data resulted in a comparable percent impervious for similar land use classifications as the analysis performed on the 1989/1991 and 2007/2002 data.

The average imperviousness values for each land use type, based on the 1989 and 2007 analyses, are summarized in Table 2-3.

Table 2-3 Average Imperviousness and Runoff Coefficient by Land Use Type for Bloomington based on the 1989/1991 and 2007/2002 Land Use/Imperviousness Data

Land Use Class	Percent Imperviousness	Runoff Coefficient (RC)
Agriculture	9.4%	0.11
Commercial	75.2%	0.73
Developed Park	17.9%	0.21
Forest	4.2%	0.03
Grassland	18.1%	0.03
High Density Residential	50.3%	0.50
Highway	58.3%	0.57
Industrial	74.8%	0.72
Institutional	46.5%	0.47
Low Density Residential	29.0%	0.31
Medium Density Residential	40.7%	0.42

2.2.1 2020 Imperviousness Determinations

To estimate the acres of imperviousness for 2020, the average percent impervious for each land use class (see Table 2-3) was applied to the planned 2020 land use layer. The estimated imperviousness for Bloomington's future land use is summarized in Table 2-2.

2.2.2 Summary of Land Use/Land Cover by Watershed

ArcMap GIS was used to intersect the 24 drainage basin divides, provided by the city of Bloomington, with the land use and imperviousness data for 1989, 2007, and 2020. The city was further divided based on the jurisdictional extent of the MS4 permit. Therefore, Hennepin County and Mn/DOT right-of-way were removed from the analysis area. The data were summarized by land use for each basin to develop inputs for estimating runoff volume, TP and TSS loading. The land use/land cover characteristics are summarized for each of the 24 drainage basins (excluding County and State right-of-ways) in Table 2-4.

Table 2-4 Bloomington Land Use by Basin for 1989, 2007 and 2020

WMO/WD	Basin	Land Use	Area (acres) by Year		
			1988	2007	2020
Lower Minnesota River Watershed District	**10th Ave.**	Agriculture	0.0	0.0	0.0
		Commercial	0.0	0.0	0.0
		Developed Park	1.5	0.0	0.0
		Forest	0.0	0.0	0.0
		Grassland	0.2	1.5	1.5
		High Density Residential	0.0	0.0	0.0
		Highway	0.0	0.0	0.0
		Industrial	6.1	6.1	6.1
		Institutional	0.0	0.0	0.0
		Low Density Residential	80.2	79.7	79.7
		Medium Density Residential	0.0	0.7	0.7
		Water	0.0	0.0	0.0
		TOTAL	88.0	88.0	88.0
		Area Impervious[1]	28.1	28.2	28.2
		Percent Impervious[2]	31.9	32.1	32.1
	3rd Ave.	Agriculture	0.0	0.0	0.0
		Commercial	1.5	1.5	1.5
		Developed Park	2.4	2.4	2.4
		Forest	0.0	0.0	0.0
		Grassland	0.9	0.4	0.4
		High Density Residential	5.4	5.4	5.4
		Highway	0.0	0.0	0.0
		Industrial	0.0	0.0	0.0
		Institutional	29.2	29.2	29.2
		Low Density Residential	193.0	193.5	193.5
		Medium Density Residential	0.0	0.0	0.0
		Water	0.0	0.0	0.0
		TOTAL	232.3	232.3	232.3
		Area Impervious[1]	74.0	74.0	74.0
		Percent Impervious[2]	31.8	31.9	31.9
	Airport South	Agriculture	14.8	14.8	0.5
		Commercial	326.6	373.3	409.7
		Developed Park	0.0	34.7	36.4
		Forest	9.1	15.4	10.4
		Grassland	86.4	16.2	12.3
		High Density Residential	59.2	51.7	42.9
		Highway	1.7	1.7	1.7
		Industrial	85.3	72.2	72.2
		Institutional	9.7	10.4	10.4
		Low Density Residential	85.5	81.5	75.5
		Medium Density Residential	2.6	4.9	4.9
		Water	0.1	4.3	4.3
		TOTAL	681.1	681.1	681.1
		Area Impervious[1]	388.1	403.5	422.8
		Percent Impervious[2]	57.0	59.6	62.5

1 - Area of Impervious does not include the water/wetland area, which was assumed to be 100 percent impervious
2 - Calculation of the Percent Impervious does not include the Water/Wetland area in the Total Area

Table 2-4: Bloomington Land Use by Basin for 1988, 2007 and 2020 (Cont.)

WMO/WD	Basin	Land Use	Area (acres) by Year 1988	2007	2020
Lower Minnesota River Watershed District (cont.)					
	France Ave.	Agriculture	0.0	0.0	0.0
		Commercial	1.1	1.1	1.1
		Developed Park	1.8	1.8	1.8
		Forest	3.7	3.7	3.7
		Grassland	1.9	2.1	1.1
		High Density Residential	1.8	1.8	1.8
		Highway	0.0	0.0	0.0
		Industrial	0.0	0.0	0.0
		Institutional	18.1	18.1	18.1
		Low Density Residential	201.2	199.6	199.7
		Medium Density Residential	0.0	1.4	2.4
		Water	3.5	3.5	3.5
		TOTAL	233.0	233.0	233.0
		Area Impervious[1]	69.3	69.4	69.6
		Percent Impervious[2]	30.2	30.3	30.4
	Hampshire Pond	Agriculture	0.0	0.0	0.0
		Commercial	47.0	54.7	56.1
		Developed Park	159.3	160.6	160.5
		Forest	32.3	26.7	26.4
		Grassland	279.6	79.9	79.7
		High Density Residential	90.4	111.9	147.7
		Highway	0.0	0.0	0.0
		Industrial	188.1	362.5	364.4
		Institutional	85.4	71.7	47.5
		Low Density Residential	220.2	228.9	206.5
		Medium Density Residential	32.8	35.2	43.2
		Water	22.1	24.9	24.9
		TOTAL	1157.1	1157.1	1157.1
		Area Impervious[1]	418.9	527.0	533.0
		Percent Impervious[2]	36.9	46.5	47.1
	Hopkins Road	Agriculture	0.0	0.0	0.0
		Commercial	34.9	34.3	34.3
		Developed Park	0.0	6.7	6.7
		Forest	29.4	29.6	23.4
		Grassland	20.7	16.6	9.3
		High Density Residential	42.8	52.9	52.9
		Highway	6.3	6.3	6.3
		Industrial	29.0	29.0	17.5
		Institutional	13.6	13.6	13.6
		Low Density Residential	356.3	349.7	349.4
		Medium Density Residential	6.9	2.0	27.3
		Water	35.2	34.5	34.5
		TOTAL	575.0	575.0	575.0
		Area Impervious[1]	190.6	191.7	191.8
		Percent Impervious[2]	35.3	35.5	35.5

1 - Area of Impervious does not include the water/wetland area, which was assumed to be 100 percent impervious
2 - Calculation of the Percent Impervious does not include the Water/Wetland area in the Total Area

Table 2-4: Bloomington Land Use by Basin for 1988, 2007 and 2020 (Cont.)

WMO/WD	Basin	Land Use	Area (acres) by Year		
			1988	2007	2020
Lower Minnesota River Watershed District (cont.)					
	Minnesota River Direct	Agriculture	42.7	42.7	24.2
		Commercial	26.6	57.4	78.1
		Developed Park	34.5	34.5	34.5
		Forest	905.4	947.9	942.3
		Grassland	214.6	55.1	50.2
		High Density Residential	42.8	36.2	36.3
		Highway	6.7	9.6	9.6
		Industrial	8.4	11.4	11.4
		Institutional	24.6	31.1	31.1
		Low Density Residential	475.3	533.6	545.9
		Medium Density Residential	3.9	24.9	24.9
		Water	2615.0	2617.2	2612.0
		TOTAL	4400.5	4401.6	4400.5
		Area Impervious[1]	289.9	315.1	331.4
		Percent Impervious[2]	16.2	17.7	18.5
	Overlook Lake	Agriculture	0.0	0.0	0.0
		Commercial	11.0	5.9	3.6
		Developed Park	8.3	9.2	9.2
		Forest	1.6	0.7	0.6
		Grassland	20.4	0.7	0.3
		High Density Residential	0.0	10.8	10.8
		Highway	0.0	0.0	0.0
		Industrial	20.5	27.2	29.5
		Institutional	0.9	6.5	6.4
		Low Density Residential	356.3	355.2	353.5
		Medium Density Residential	54.6	57.4	59.7
		Water	6.7	6.7	6.7
		TOTAL	480.4	480.4	480.4
		Area Impervious[1]	154.9	161.5	161.8
		Percent Impervious[2]	32.7	34.1	34.1
	South Glen	Agriculture	0.0	0.0	0.0
		Commercial	71.1	63.2	63.2
		Developed Park	8.4	7.9	7.9
		Forest	0.0	17.2	17.2
		Grassland	37.3	13.0	13.0
		High Density Residential	61.2	68.5	68.5
		Highway	0.0	0.0	0.0
		Industrial	0.0	0.0	0.0
		Institutional	51.6	60.2	59.5
		Low Density Residential	385.9	382.3	379.3
		Medium Density Residential	25.0	28.2	31.9
		Water	39.0	39.1	39.1
		TOTAL	679.6	679.6	679.6
		Area Impervious[1]	238.6	236.8	237.1
		Percent Impervious[2]	37.3	37.0	37.0

1 - Area of Impervious does not include the water/wetland area, which was assumed to be 100 percent impervious
2 - Calculation of the Percent Impervious does not include the Water/Wetland area in the Total Area

Table 2-4: Bloomington Land Use by Basin for 1988, 2007 and 2020 (Cont.)

WMO/WD	Basin	Land Use	Area (acres) by Year 1988	2007	2020
Lower Minnesota River Watershed District (cont.)					
	York Ave.	Agriculture	0	0	0
		Commercial	17.68422	15.45888	15.45933
		Developed Park	94.25335	87.73682	87.7368
		Forest	31.78735	36.01252	27.50575
		Grassland	5.630084	3.929717	3.646495
		High Density Residential	12.42503	14.961	16.00729
		Highway	0	0	0
		Industrial	0	0	0
		Institutional	13.1903	15.41565	15.41565
		Low Density Residential	351.65	352.9808	357.8369
		Medium Density Residential	0	0	2.887194
		Water	102.844	102.9689	102.9689
		TOTAL	629.4643	629.4643	629.4643
		Area Impervious[1]	146.9331	146.6569	149.357
		Percent Impervious[2]	27.9	27.9	28.4

WMO/WD	Basin	Land Use	Area (acres) by Year 1988	2007	2020
Nine Mile Creek Watershed District	494 East	Agriculture	0.0	0.0	0.0
		Commercial	30.6	43.2	44.5
		Developed Park	0.0	0.0	0.0
		Forest	0.0	0.0	0.0
		Grassland	10.5	1.6	0.3
		High Density Residential	0.0	0.0	0.0
		Highway	0.9	0.9	0.9
		Industrial	6.0	1.9	1.9
		Institutional	0.0	0.0	0.0
		Low Density Residential	0.0	0.0	0.0
		Medium Density Residential	1.0	1.0	1.0
		Water	0.0	0.4	0.4
		TOTAL	49.0	49.0	49.0
		Area Impervious[1]	30.4	35.1	35.9
		Percent Impervious[2]	61.9	72.3	73.8
	Brook Side	Agriculture	0.0	0.0	0.0
		Commercial	8.2	5.1	5.1
		Developed Park	0.0	0.0	0.0
		Forest	0.4	0.9	0.9
		Grassland	2.3	1.8	1.8
		High Density Residential	5.3	5.3	5.3
		Highway	0.0	0.0	0.0
		Industrial	0.0	0.0	0.0
		Institutional	29.0	32.1	32.1
		Low Density Residential	230.8	230.8	230.8
		Medium Density Residential	0.0	0.0	0.0
		Water	7.7	7.7	7.7
		TOTAL	283.8	283.8	283.8
		Area Impervious[1]	89.7	88.8	88.8
		Percent Impervious[2]	32.5	32.2	32.2

1 - Area of Impervious does not include the water/wetland area, which was assumed to be 100 percent impervious
2 - Calculation of the Percent Impervious does not include the Water/Wetland area in the Total Area

Table 2-4: **Bloomington Land Use by Basin for 1988, 2007 and 2020 (Cont.)**

WMO/WD	Basin	Land Use	Area (acres) by Year		
			1988	2007	2020
Nine Mile Creek Watershed District (cont.)					
	Bush Lake	Agriculture	0.0	0.0	0.0
		Commercial	4.2	1.9	1.9
		Developed Park	11.5	56.2	56.2
		Forest	265.4	272.6	272.1
		Grassland	344.7	242.8	242.1
		High Density Residential	4.3	4.3	4.3
		Highway	0.0	0.0	0.0
		Industrial	0.0	0.0	0.0
		Institutional	2.0	4.8	4.2
		Low Density Residential	264.7	309.9	311.8
		Medium Density Residential	0.0	3.5	3.5
		Water	286.8	287.5	287.5
		TOTAL	1183.5	1183.5	1183.5
		Area Impervious[1]	158.7	162.7	162.8
		Percent Impervious[2]	17.7	18.2	18.2
	Lower Nine Mile Creek	Agriculture	0.0	0.0	0.0
		Commercial	13.6	18.2	17.9
		Developed Park	0.0	0.0	0.0
		Forest	189.3	196.1	193.8
		Grassland	27.0	9.3	5.8
		High Density Residential	61.9	63.2	63.2
		Highway	1.3	1.3	1.3
		Industrial	3.1	2.4	4.7
		Institutional	71.0	56.6	56.6
		Low Density Residential	896.5	903.9	907.8
		Medium Density Residential	16.7	26.1	26.1
		Water	95.1	98.5	98.5
		TOTAL	1375.5	1375.5	1375.5
		Area Impervious[1]	357.1	357.1	358.9
		Percent Impervious[2]	27.9	28.0	28.1
	Marsh Lake	Agriculture	0.0	0.0	0.0
		Commercial	8.3	8.0	8.0
		Developed Park	0.0	0.0	0.0
		Forest	23.6	23.7	23.7
		Grassland	9.8	1.8	1.7
		High Density Residential	23.8	24.2	24.4
		Highway	0.0	0.0	0.0
		Industrial	0.0	0.0	0.0
		Institutional	36.1	36.1	36.1
		Low Density Residential	247.2	252.8	252.5
		Medium Density Residential	26.4	28.4	28.6
		Water	55.3	55.4	55.4
		TOTAL	430.5	430.5	430.5
		Area Impervious[1]	120.2	121.2	121.3
		Percent Impervious[2]	32.0	32.3	32.3

1 - Area of Impervious does not include the water/wetland area, which was assumed to be 100 percent impervious
2 - Calculation of the Percent Impervious does not include the Water/Wetland area in the Total Area

Table 2-4: Bloomington Land Use by Basin for 1988, 2007 and 2020 (Cont.)

WMO/WD	Basin	Land Use	Area (acres) by Year 1988	2007	2020
Nine Mile Creek Watershed District (cont.)					
	Oxboro Lake	Agriculture	0.0	0.0	0.0
		Commercial	267.1	251.7	255.6
		Developed Park	61.6	61.6	61.6
		Forest	9.3	3.8	3.8
		Grassland	41.8	30.7	18.2
		High Density Residential	124.9	143.2	145.1
		Highway	7.0	7.0	7.0
		Industrial	519.8	493.8	504.5
		Institutional	77.6	129.7	129.7
		Low Density Residential	862.1	842.5	839.2
		Medium Density Residential	5.3	9.8	9.3
		Water	25.6	28.1	28.1
		TOTAL	2002.1	2002.1	2002.1
		Area Impervious[1]	964.0	960.4	968.8
		Percent Impervious[2]	48.8	48.7	49.1
	Penn Lake	Agriculture	0.0	0.0	0.0
		Commercial	179.0	187.7	193.0
		Developed Park	28.7	36.0	36.0
		Forest	7.8	3.1	3.1
		Grassland	8.7	7.9	6.8
		High Density Residential	25.5	29.7	38.7
		Highway	4.1	4.1	4.1
		Industrial	52.1	42.6	42.6
		Institutional	110.7	102.0	89.0
		Low Density Residential	719.2	718.6	718.6
		Medium Density Residential	0.7	4.8	4.8
		Water	67.6	67.6	67.6
		TOTAL	1204.2	1204.2	1204.2
		Area Impervious[1]	456.3	456.3	458.5
		Percent Impervious[2]	40.1	40.1	40.3
	Skriebakken	Agriculture	0.0	0.0	0.0
		Commercial	104.6	106.6	106.6
		Developed Park	12.6	12.6	12.6
		Forest	15.0	42.0	42.0
		Grassland	35.4	4.0	4.0
		High Density Residential	41.2	41.6	51.0
		Highway	0.0	0.0	0.0
		Industrial	15.5	15.5	6.2
		Institutional	35.3	35.3	35.3
		Low Density Residential	428.3	429.5	429.5
		Medium Density Residential	7.4	7.4	7.4
		Water	83.7	84.6	84.6
		TOTAL	779.2	779.2	779.2
		Area Impervious[1]	264.1	261.5	259.2
		Percent Impervious[2]	38.0	37.7	37.3

1 - Area of Impervious does not include the water/wetland area, which was assumed to be 100 percent impervious
2 - Calculation of the Percent Impervious does not include the Water/Wetland area in the Total Area

Table 2-4: Bloomington Land Use by Basin for 1988, 2007 and 2020 (Cont.)

WMO/WD	Basin	Land Use	Area (acres) by Year 1988	2007	2020
Nine Mile Creek Watershed District (cont.)					
	Upper Nine Mile Creek	Agriculture	0.0	0.0	0.0
		Commercial	304.8	316.3	340.3
		Developed Park	27.6	47.0	47.0
		Forest	439.2	477.1	468.1
		Grassland	222.5	102.4	86.2
		High Density Residential	67.7	69.3	69.4
		Highway	14.9	23.9	23.9
		Industrial	72.5	66.4	66.3
		Institutional	62.2	77.9	75.3
		Low Density Residential	741.4	740.6	746.4
		Medium Density Residential	33.3	61.8	59.8
		Water	814.6	817.9	817.9
		TOTAL	2800.6	2800.6	2800.6
		Area Impervious[1]	647.6	659.8	674.1
		Percent Impervious[2]	32.6	33.3	34.0
	West Marsh Lake	Agriculture	0.0	0.0	0.0
		Commercial	4.1	4.1	4.1
		Developed Park	25.5	25.0	25.0
		Forest	0.0	5.0	5.0
		Grassland	10.8	0.4	0.4
		High Density Residential	16.2	21.9	21.9
		Highway	0.0	0.0	0.0
		Industrial	0.0	0.0	0.0
		Institutional	42.0	42.0	42.0
		Low Density Residential	193.5	194.1	194.1
		Medium Density Residential	0.0	0.0	0.0
		Water	5.8	5.5	5.5
		TOTAL	298.0	298.0	298.0
		Area Impervious[1]	93.5	94.7	94.7
		Percent Impervious[2]	32.0	32.4	32.4

WMO/WD	Basin	Land Use	Area (acres) by Year 1988	2007	2020
Richfield-Bloomington Watershed Management Organization	**Smith Pond**	Agriculture	0.0	0.0	0.0
		Commercial	129.4	162.5	162.5
		Developed Park	32.6	30.9	30.9
		Forest	2.9	3.1	3.1
		Grassland	12.7	8.2	8.2
		High Density Residential	104.6	104.9	110.9
		Highway	7.8	7.8	7.8
		Industrial	164.7	140.4	140.4
		Institutional	57.5	68.0	68.0
		Low Density Residential	1113.3	1111.6	1111.6
		Medium Density Residential	22.8	10.5	4.6
		Water	14.9	15.4	15.4
		TOTAL	1663.4	1663.4	1663.4
		Area Impervious[1]	645.0	650.1	650.7
		Percent Impervious[2]	39.1	39.4	39.5

1 - Area of Impervious does not include the water/wetland area, which was assumed to be 100 percent impervious
2 - Calculation of the Percent Impervious does not include the Water/Wetland area in the Total Area

Table 2-4: **Bloomington Land Use by Basin for 1988, 2007 and 2020 (Cont.)**

WMO/WD	Basin	Land Use	Area (acres) by Year		
			1988	2007	2020
Richfield-Bloomington Watershed Management Organization (cont.)					
	11th Ave.	Agriculture	0.0	0.0	0.0
		Commercial	0.0	0.0	0.0
		Developed Park	9.0	7.6	7.6
		Forest	0.0	0.0	0.0
		Grassland	2.6	3.5	3.5
		High Density Residential	4.4	0.0	0.0
		Highway	0.0	0.0	0.0
		Industrial	13.3	13.3	13.3
		Institutional	15.1	19.5	19.5
		Low Density Residential	292.7	292.7	292.7
		Medium Density Residential	3.2	3.8	3.8
		Water	2.1	2.1	2.1
		TOTAL	342.4	342.4	342.4
		Area Impervious[1]	107.5	107.4	107.4
		Percent Impervious[2]	31.6	31.6	31.6

WMO/WD	Basin	Land Use	Area (acres) by Year		
			1988	2007	2020
Riley-Purgatory-Bluff Creek Watershed District	**Colorado Pond**	Agriculture	0.0	0.0	0.0
		Commercial	14.8	17.0	17.0
		Developed Park	119.9	119.8	119.8
		Forest	114.1	150.8	150.8
		Grassland	155.7	114.1	114.1
		High Density Residential	14.6	15.3	15.5
		Highway	0.0	0.0	0.0
		Industrial	0.0	0.0	0.0
		Institutional	11.7	16.5	16.5
		Low Density Residential	301.2	299.4	299.4
		Medium Density Residential	38.4	39.5	39.3
		Water	120.6	118.4	118.4
		TOTAL	890.9	890.9	890.9
		Area Impervious[1]	181.4	179.6	179.6
		Percent Impervious[2]	23.5	23.2	23.3
	Riley Purgatory	Agriculture	0.0	0.0	0.0
		Commercial	27.7	27.5	27.5
		Developed Park	20.1	35.7	35.7
		Forest	28.8	36.9	36.6
		Grassland	133.3	44.5	43.7
		High Density Residential	45.0	45.0	45.0
		Highway	2.5	13.2	13.2
		Industrial	0.0	0.0	0.0
		Institutional	34.3	18.7	18.7
		Low Density Residential	516.0	562.2	563.2
		Medium Density Residential	112.6	137.4	137.4
		Water	90.2	89.5	89.5
		TOTAL	1010.4	1010.4	1010.4
		Area Impervious[1]	285.3	294.7	294.9
		Percent Impervious[2]	31.0	32.0	32.0

1 - Area of Impervious does not include the water/wetland area, which was assumed to be 100 percent impervious
2 - Calculation of the Percent Impervious does not include the Water/Wetland area in the Total Area

2.3 Modeling Approach and Methodology for Loading Estimates

Complex models used to answer simple questions are not advantageous and simple models that do not model important or required physical processes are not useful. In keeping with the Permit conditions and guidance discussed in Section 1.2 of this report, our modeling approach was developed based on the following requirements:

- The loading assessment should include changes to pollutant loadings associated with changes due to past land use changes and changes due to anticipated land use changes.
- The modeling will produce relative values, as the MPCA is more concerned with the average annual increases than about specific event increases. It is not as important to get the actual loads correct as it is to model consistently, showing the relative change in loads rather than the actual loads.
- The assessment can include changes due to BMPs that have already been implemented, if increase in the loading since 1989 is explicitly stated, as well as changes due to BMPs that are planned to be implemented and written into the MS4's ordinances or other regulatory mechanisms.
- The model does not need to calculate design features such as hydrographs, but can show removal rates based on design criteria, which can be just as useful for planning purposes. Design calculations may need to be run before implementation but often these can be run on a much smaller scale.

Currently, there are several water quality models available for simulating urban runoff and the treatment effectiveness of BMPs. Table 2-5 presents a qualitative comparison of several of the important attributes associated with some of the more common runoff water quality model capabilities based on the various selection criteria. The compiled model attributes and capabilities come primarily from peer-reviewed manuals (U.S. EPA, 1997; Burton and Pitt, 2001), with additional updated information based on our own experience and professional judgment. The water quality models included in the table are generally listed in increasing order of complexity (from left to right). For each attribute or selection criteria the models are categorized by possessing low, medium (intermediate) or high capabilities. Those capabilities that are not incorporated into a particular model, or were not applicable, were also indicated. Our approach for model selection for this assessment involved comparison of the advantages and limitations of the various models as they pertain to the Permit requirements, available data, and objectives of the City.

Table 2-5 shows that the only limitation with the P8 model, as it relates to the modeling requirements for the loading assessment, is that it is not intended to be used to determine pollutant loadings from non-urban land uses. However, the Simple Method, PONDNET and Generalized Watershed Loading Functions (GWLF) can be used to determine pollutant loadings from both urban and non-urban land uses. Both the Simple Method and PONDNET are typically used on an annual time scale. Table 2-5 also shows that the Simple Method, PONDNET and GWLF lack the ability to model the BMPs that would typically be considered for implementation by the City (such as vegetated drainage ways, extended detention, infiltration/filtration practices and street sweeping). Source Loading and Management Model (SLAMM) lacks a snowmelt runoff routine, does not have any capabilities for including baseflow in BMP analysis, and does not have the model output features contained in the P8 model. XP-SWMM is more complex, but is not in the public domain, is significantly more expensive, and BMP modeling is more cumbersome, less accurate and less intuitive than the P8 model.

Table 2-5 Comparison of Modeling Attributes/Capabilities by Selection Criteria

Criteria/Attributes		Simple Method	PONDNET	SLAMM	P8	GWLF	XP-SWMM
Time Scale	Annual	H	H	--	--	--	--
	Single Event	H	--	--	H	--	H
	Continuous	--	--	H	H	H	H
Hydrology	Runoff	L	L	H	H	H	H
	Baseflow	--	--	--	L	H	H
	Snowmelt	--	--	--	H	--	H
Pollutant Loading (Constituents)	Sediment (TSS)	H	--	H	H	H	H
	Nutrients	H	H	H	H	H	H
Pollutant Loading (Land Uses)	Urban	H	H	H	H	H	H
	Agricultural	H	H	--	--	H	--
Pollutant Routing	Transport	--	--	L	L	L	H
	Erosion	--	--	--	--	H	H
	Transformation	--	--	--	--	--	L
Hydraulic Flow Routing/Diversions		--	--	--	L	L	H
Model Output	Statistics	L	L	L	H	L	H
	Graphics	--	--	L	H	M	H
	Hydro/Pollutographs	--	--	--	H	--	H
	Format Options	L	L	H	H	H	H
	Sensitivity Analysis	--	--	--	H	--	--
Input Data	Requirements	L	L	M	M	M	H
	Calibration	L	L	L	M	L	H
	Default Data	L	H	H	H	H	M
	User Interface	L	L	H	H	H	H
GIS Compatibility		L	L	--	M	L	M
BMPs-General	Evaluation	--	H	M	H	L	H
	Design Criteria	--	H	L	H	--	H
Specific BMPs	Ponds/Wetlands	--	H	H	H	--	H
	Extended Detention	--	--	M	H	--	H
	Infiltration/Filtration	--	--	H	H	--	M
	Street Sweeping	--	--	H	H	--	M
	Others	--	--	H	H	--	L
Documentation	Peer Acceptance	H	H	H	H	H	H
	Technical Support	L	L	M	H	L	H
Cost	Software	L	L	M	L	L	H
	Use	L	L	M	M	M	H

H = High **M** = Medium (Intermediate) **L** =Low **--** = Not Incorporated (Not Applicable)

For this loading assessment, we have chosen to use the Simple Method to determine the pollutant loadings and runoff volumes from each of the land uses within each watershed and then use the P8 model to account for the effects of BMP implementation for the time periods of interest in the Permit conditions. In addition to the discussion associated with Table 2-5, the following information provides further justification for choosing the Simple Method/P8 model combination for the loading assessment modeling, in comparison to SLAMM, PONDNET, XP-SWMM, or some combination thereof:

- The Simple Method inputs can be directly derived within GIS.
- PONDNET does not model TSS loadings and is only intended for modeling TP within wet detention ponds.
- SLAMM is more detailed than P8 with respect to distinguishing source loading areas (such as driveways, parking lots, lawns, etc.), but P8 exceeds the capabilities of SLAMM when it comes to networking of watersheds/BMPs and many of the graphics and advanced output features.
- P8 provides routines for performing sensitivity analyses and can also be run in design mode to determine required sizes of BMP(s) to meet treatment criteria.
- P8 has the highest peer acceptance in Minnesota for urban runoff and BMP water quality modeling and enhancements have been supported by the MPCA.
- P8 is free, user-friendly and easy to learn with its menu driven system.
- P8 allows for some GIS compatibility via ASCII text file import of watershed data and export of results.
- P8 models actual hourly precipitation and climatic data as it occurs, with its associated antecedent moisture conditions, while SLAMM only reads in the total precipitation and duration of each rainfall event and does not model actual runoff events in real-time with their associated antecedent moisture conditions.
- Unlike SLAMM, P8 allows for hydrologic calibration within the program and can be calibrated/validated to time series runoff events continuously simulated from climatic data.

The city of Bloomington has conducted a significant amount of monitoring of stormwater runoff and receiving water quality/quantity. These monitoring locations were generally selected to isolate and monitor runoff from individual land uses or specific land cover types. Additionally, P8 Models have been developed, and calibrated with the available data, for portions of the city as part of diagnostic-feasibility studies. However, the P8 Models are not representative of either 1989 or current (2007) land use conditions, they include natural wetlands in the modeling network, and do not include all of the individual BMPs for each developed site within the watershed (typically due to a lack of site-specific BMP information for each site and the size limitation of the model). Since the presence of natural wetlands in the modeled drainage systems would affect the downstream water and pollutant loadings, it would not accurately distinguish between the expected treatment levels or provide a truly relative comparison between the predicted loadings, with and without the presence of the watershed BMPs.

Following the initial assessment of TSS, TP and volume contributions with the Simple Method, we will then assess the benefit that current BMP implementation has had on the flow, TP and TSS loadings within the city limits using the P8 water quality modeling for developments based on P8 model design criteria examples that are indicative of the ordinances and design standards that were in place by the City, the watershed management organizations, the WCA and the MPCA when development occurred. Based on the available data, combining the Simple Method and P8 Model for the loading assessment ensures full compliance with the Permit requirements, for the following reasons:

- The Simple Method ensures that a consistent method for calculating average annual volumes and loadings will be applied to all land uses to produce relative values across the two times periods of interest, as discussed in the Permit and Guidance Manual (see Sections 1.1.1 and 1.2.2.1 of this report).
- The P8 Model simulations of volume and pollutant loading reductions associated with BMP implementation, according to the various ordinances and design standards that were in place when development occurred, is consistent with the Permit conditions and Guidance Manual and provides a consistent method for calculating relative removal rates as suggested in Section 1.2.2.1 of this report.
- Excludes the effects that natural wetlands would have on improving the stormwater quality within each watershed, which ensures that the loading assessment estimates that include BMPs do not take credit for treatment by natural wetlands
- The City will not have to revise and update existing P8 models to exclude the effects of natural wetlands or collect significantly more data on every BMP to develop new P8 models for the rest of the city, which would represent significantly more cost for a product that would not provide a “distinction between what is desirable and what is required. The MPCA chose a level [in its loading assessment requirements] that will prevent undue burden while still developing useful information.” (MPCA Guidance Manual, 2006).

The loading assessment modeling results were summarized for each of the 24 drainage basins to show the Simple Method loading and volume estimates for each time period, as well as the loading and volume estimates after applying the P8 model design criteria examples, based on the ordinances and design standards that were in place when the various developments occurred.

2.3.1 Average Annual Flow Volume

The conversion of land areas from agricultural or undeveloped areas to urban land uses and the redevelopment of urban lands to higher density uses leads to changes in watershed hydrology and pollutant load rates. The areal increase in impervious surfaces associated with development or redevelopment can lead to greater surface water runoff volumes. The increased runoff coupled with human activities increases the types of pollutants and delivery rate of these pollutants to surface waters. Impermeable surfaces shed water as surface runoff which reduces the infiltration and evapotranspiration components of the hydrologic cycle. Surface runoff in urbanized areas is generally directed to storm sewers and other conveyance systems to rapidly move the large volumes to receiving waters and prevent flooding. This section provides a general discussion about the methodology used to quantify the amount of runoff from the various land uses in the Bloomington watersheds during the two time periods of interest for the Permit conditions.

As previously discussed, the Simple Method was used to estimate the average annual runoff volumes, which in turn, are also used to calculate the TP and TSS loadings, for the various land uses present within the Bloomington watersheds. In the urbanized portion of each watershed, average annual runoff volume was calculated using the following relationships (as described in Schueler, 1987) by land use type:

Annual Runoff Coefficient [RC] = 0.05 + ((0.009) x (Impervious Fraction) x 100)

Annual Runoff Volume (acre-feet) = RC x Annual Rainfall (inches) x Land Use Area (acres) / 12

The annual runoff coefficients (percentage of rainfall resulting in runoff) are summarized in Table 2-6 by land use type. Runoff coefficients for grassland, hay/pasture, and forest land uses were based on a review of the available literature and estimates using curve number methodology and are also summarized in Table 2-3. Reckhow et al. (1980) summarized the TP and water yield monitoring results of several published monitoring studies throughout the country that were specific to individual land uses or land cover types. All of the available water runoff and rainfall volume data were taken from Reckhow et al. (1980) and used to determine the median runoff coefficient for the hay/pasture land use category. The median runoff coefficient for the hay/pasture land use category was 0.11. For the forested land use, curve number methodology, assuming good ground cover, was applied to the long-term Twin City rainfall records to estimate that the relative event-based cumulative runoff coefficient was 0.03. It was assumed that grassland would exhibit the same runoff coefficient as forestland. Each of these runoff coefficients, for non-urban land uses, show good relative agreement with the urban pervious runoff coefficient of 0.05 shown above (taken from Schueler [1987]).

There are several flow and water quality monitoring stations along the length of Nine Mile Creek within Bloomington. To verify that the runoff coefficients used in this analysis were reasonable, an analysis of the 2005 precipitation, slightly less than average precipitation, and flow data for the monitoring station located at 98th Street was evaluated to estimate a runoff coefficient representative of the development conditions within the city. Results of this analysis indicate that the unit runoff typical for the city of Bloomington is about 6 inches of runoff per year. The method used for this loading assessment results in an average unit runoff of 12 inches. Although the simple method appears to over-estimate the annual runoff volume for Nine Mile Creek, the methodology yields a conservative estimate of the runoff from Bloomington.

2.3.2 Total Phosphorus

As previously discussed, there is some monitoring data available for runoff volumes or quality from individual land uses or specific land cover types within the city of Bloomington. However, after reviewing this data, it was determined that the data was limited to a few monitoring locations with only a small number of runoff events monitored, incomplete coverage of the land uses used in this analysis, and unreasonably high values for some sampling events. Therefore, the expected TP concentration by urban land use type was estimated using the concentrations listed in the *2005 MPCA Minnesota Storm Water Manual* (Table 8.7). The land use specific TP concentrations used for Bloomington's loading assessment are summarized in Table 2-6.

Phosphorus loading from urbanized portion of each watershed was then calculated according to the following equation:

TP Load (lbs.) = Land Use Runoff Conc. (mg/L) x *Annual Runoff Volume (acre-feet)* x *2.72*.

The TP contributions from non-urban land uses were based on Reckhow et al. (1980), which summarized the TP export coefficients produced from several published monitoring studies throughout the country that were specific to individual land uses or land cover types. All of the available TP export coefficient data were taken from Reckhow et al. (1980) and used to determine the median export coefficients for the hay/pasture and forested land use categories. The median TP export coefficients for the hay/pasture and forested land use categories were 0.54 and 0.09 lbs/ac/yr, respectively. It was assumed that grassland would exhibit the same TP export coefficient as forestland. Because Bloomington is fully-developed and there was only one agricultural parcel of land in 1989 and 2007, the agricultural parcel was assumed to be hay/pasture as the land cover.

The average annual phosphorus loading from non-urban land uses in each watershed was then calculated according to the following equation:

TP Load (lbs.) = Land Use Area (acres) x TP Export Coefficient (lbs/ac/yr)

2.3.3 Total Suspended Solids

As previously discussed, there is some monitoring data available for runoff water quality from individual land uses within the city. However, for the same reasons discussed in the TP section above, this monitoring data was not used for the loading analysis. Therefore, the expected TSS concentrations by urban land use were taken from Pitt (2003). TSS loading from urbanized portion of each watershed was then calculated according to the following equation:

TSS Load (lbs.) = Land Use Runoff Conc. (mg/L) x *Annual Runoff Volume (acre-feet)* x *2.72*

The TSS contributions from non-urban land uses were based on several literature sources (MCES, 2004; DeByle and Packer, 1972; Harms et al., 1974; Webber and Elrick, 1967; Sonzogni et al., 1980), which summarized the TSS export coefficients produced from several published monitoring studies throughout the country that were specific to individual land uses or land cover types. All of the available TSS export coefficient data were taken from the literature sources and used to determine the median export coefficients for the hay/pasture and forested land use categories. The median TSS export coefficients for the hay/pasture and forested land use categories were 25 and 5 lbs/ac/yr, respectively. It was assumed that grassland would exhibit the same TSS export coefficient as forestland. The average annual TSS loading from each land use in each watershed was then calculated according to the following equation:

TSS Load (lbs.) = Land Use Area (acres) x TSS Export Coefficient (lbs/ac/yr)

Table 2-6 summarizes the TP and TSS concentrations and export coefficients used to estimate loads from each land use within the city of Bloomington.

Table 2-6 TP and TSS Concentrations and Export Coefficients by Land Use

Land Use	TP Concentration[1] (mg/L)	TP Aerial Loading Rate[2] (lbs/acre/yr)	TSS Concentration[3,4] (mg/L)		TSS Aerial Loading Rate[2] (lbs/acre/yr)
Agriculture		0.54			25
Commercial	0.22		43-54	48.5	
Developed Park	0.31		51-78	64.5	
Forest		0.09			5
Grassland		0.09			5
High Density Residential	0.3		68	68	
Highway	0.25		81-99	90	
Industrial	0.26		77-82	79.5	
Institutional	0.18		17	17	
Low Density Residential	0.3		48	48	
Medium Density Residential	0.3		48-68	58	
Water					

1 - Minnesota Stormwater Manual, Table 8.7

2 - Reckhow *et al*., 1980

3 - Table 9, Summary of Available Stormwater Data Included in NSQD, version 1.0 (From "The Design, Use, and Evaluation of Wet Detention Ponds for Stormwater Quality Management Using WinDETPOND," Pitt, 2003)

4 - For TSS loading calculations, the average of the range was used

2.3.4 BMP Implementation Modeling

As previously discussed, P8 water quality modeling was used to assess the benefit that current, and expected future, BMP implementation would have on the runoff volume and TP and TSS loadings within the city limits for developments based on the ordinances and design standards that control the treatment efficiency of the BMPs when development occurs. Watershed district rules and city ordinances were reviewed to determine the regulations that were in place between 1988 and 2007 in order to address the impacts of BMPs implemented during that time period. Prior to 1988 the City and watershed district focused on rate control. Between 1988 and 1992 both the Nine Mile Creek and Riley-Purgatory Bluff Creek Watershed Districts required developments to provide sufficient surface settling to remove the 0.1 mm particle based on a 10-year, 30-minute storm event. The NURP pond BMP design requirements have generally controlled the treatment efficiency of the BMPs associated with each new development since 1992, when the City adopted development requirements consistent with the NURP wet detention pond design standards (Walker, 1987; MPCA, 1989), and will likely be the design requirements that control the treatment efficiency for BMPs that are implemented through 2020 for each watershed in the city.

Several scenarios were evaluated to estimate the impact of water quality regulations on expected loads under future land use conditions. The first scenario evaluates expected loads related to land use only and does not account for the implementation on any BMPs (see discussion in Sections 2.3.1 to 2.3.3 of this report). A second scenario evaluates the impact of the construction of NURP ponds, as was required by past and current stormwater regulations. Because the city of Bloomington does not meet the baseline loading rates for volume under the current regulations, a third scenario evaluating the implementation of infiltration with NURP pretreatment standards was considered. A final scenario evaluated regional infiltration with NURP pretreatment on total loads from the city of Bloomington.

2.3.4.1 Implementation of NURP Ponds

The first BMPs evaluated were NURP ponds, which were the first water quality BMPs required by the City and are still currently required for new and redevelopment within the city. The NURP design scenario was run in P8 for a hypothetical low-density residential development with 25 percent imperviousness and a commercial development with 80 percent imperviousness to obtain a range of treatment efficiencies, as well as the average efficiency, that would be expected for the same design standard. For the NURP design scenario, the P8 Model estimated average TP and TSS load reductions of 56 percent and 87 percent, respectively. It was assumed that no volume reduction would be realized from implementation of the NURP design requirements.

To estimate the impact of NURP pond over the time period from 1989 to 2007 and from 2007 to 2020, it was assumed that all areas that have changed or are predicted to change in the type of land use would be regulated by the NURP-criteria. Additionally, areas that were redeveloped but not associated with a change in land use type were also identified for both periods of time. Similarly, it was assumed that redevelopment in these areas would implement NURP ponds or equivalent treatment systems.

2.3.4.2 Implementation of Infiltration Basins with NURP Pretreatment

Volume reduction will be necessary for the city of Bloomington to meet baseline conditions. As a result, P8 was used to estimate the treatment efficiency of infiltration basins with NURP pretreatment that provide for infiltration of 0.5 to 1.5 inches of runoff from the contributing watershed. The Nine Mile Creek Watershed District is currently considering an infiltration requirement of 0.75 inches as part of their 2008 rule making. The estimated volume reduction ranged between 79 percent and 96 percent for infiltration of 0.5 to 1.5 inches of runoff, respectively. Reductions in TP and TSS loads were estimated to range between 89 to 96 percent and 95 to 97 percent, respectively.

To estimate the impact of infiltration on loading from the period of 2007 to 2020, the same method used to estimate the impact of NURP ponds was used. Therefore, it was assumed that runoff from any parcels that are predicted to change in the type of land use or parcels that are expected to redevelop within the same type of land use during this period will implement the infiltration criteria mentioned above.

2.3.4.3 Implementation of Regional Infiltration Basins

Implementation of BMPs for new and redevelopment areas of Bloomington was not sufficient to reduce expected runoff volumes to baseline conditions. Therefore, potential sites for regional infiltration were identified along with the expected contributing area. City basins that contributed the largest portion of the total volume, TP, and TSS loads from Bloomington were the targeted watersheds.

Figure 2-4 shows the potential locations of the regional infiltration ponds. These sites were selected based on available open space, usually park or playlot areas, topography, and proximity to existing storm sewers. The P8 model was used to evaluate conceptual designs of each of the basins, considering the maximum amount of space available for the pond as well as the maximum potential contributing watersheds to each pond. General assumptions were made for the estimated infiltration basin depths as well as for the expected infiltration rates. A 55-year precipitation and temperature record (1949-2004) for the Minneapolis-St. Paul International Airport was used to estimate the total expected volume of infiltration over that time period. This was then converted to an expected annual infiltration volume.

Table 2-7 summarizes the input parameters for each of the regional infiltration basins as well as the results of the modeling. Results include the annual infiltration volume as well as the expected TP and TSS load reductions. The estimated volume reduction ranged from 18 to 99 percent, depending on the size of the basin and the expected contributing areas. Similarly, reductions in TP ranged from 27 to 91 percent and TSS loads were reduced by 50 to 97 percent.